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Durability of Polypropylene Tubes “DRAINTUBE”

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DURABILITY OF POLYPROPYLENE TUBES “DRAINTUBES”

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1 INTRODUCTION

1.1 Objective

- Determine the durability of draintubes, and compare with a product of reference.

1.2 Theoretical approach

1.2.1 Materials degradation

The degradation mechanism of polyolefin, as shown in figure 1, usually undergoes four stages: antioxidant depletion, induction period, acceleration period, and deceleration period.

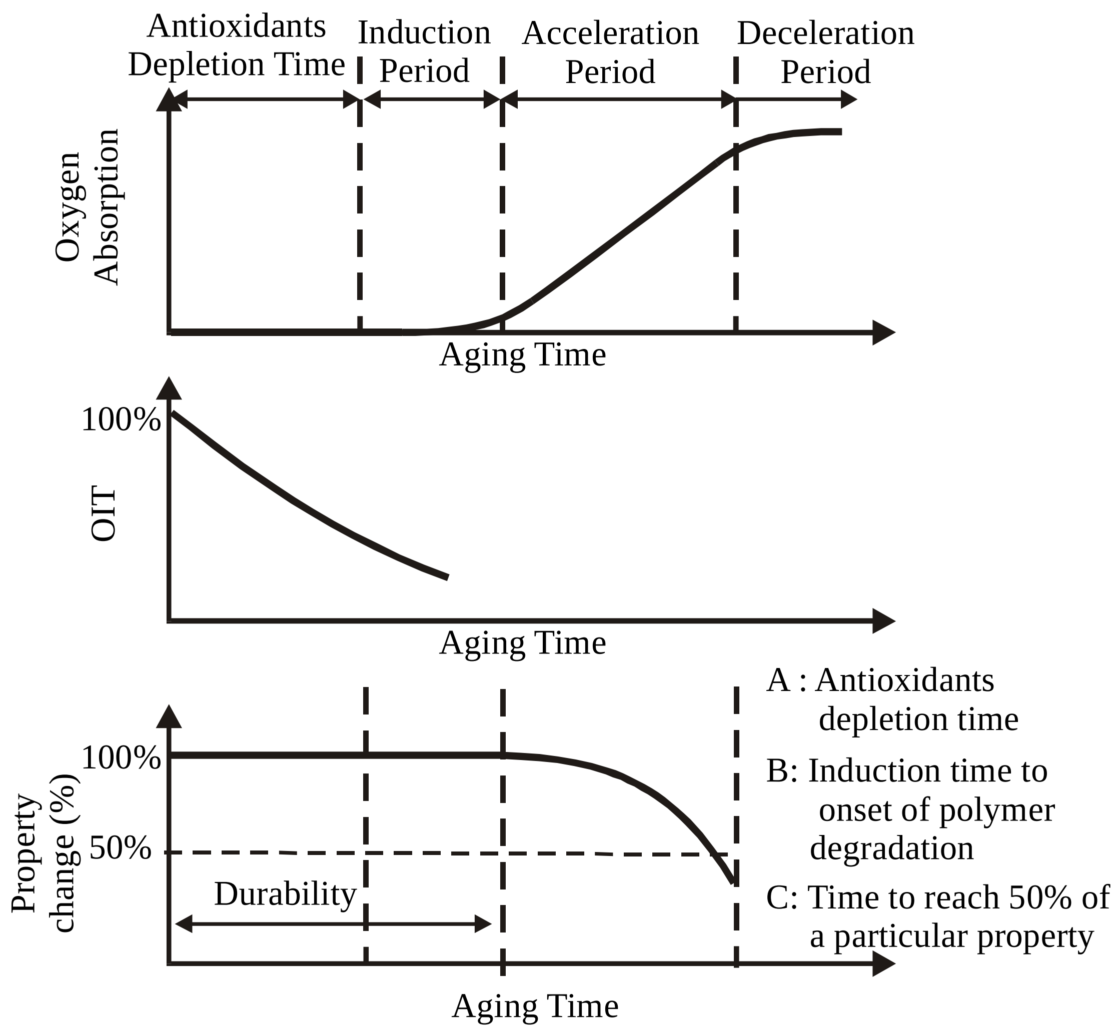

Figure 1: Degradation mechanism of polyolefin (such as polyethylene)

The antioxidant depletion is commonly monitored by the oxidative induction time (OIT), measured by differential scanning calorimetry (DSC). OIT is closely related to the amount of antioxidants remaining in the material. As a consequence, this property is an indicator of the residual life of a polyolefin product (such as polyethylene) until the antioxidants are completely depleted.

The induction period is the lag time before the chain scission of the polymer backbone will occur. During this period, it can be observed that the mechanical properties of the material do not vary significantly but the OIT has reached a value close to 'zero'.

Once the oxidation process has started, the polymer properties will change because of molecular chain scission. In addition, the melt index (ASTM D1238) will increase, as soon as the polymer molecular will decrease. Ultimately, this phenomenon leads to a reduction in mechanical properties, like compression or tension resistance.

A common approach is to determine of the 'end-of-life' criterion based on a zero OIT value. Since the oxidation and the chain scission of the polymer follows multiple oxidation reactions and side-reactions, the extrapolations of a product life might result in a false prediction. For that reason, a zero OIT criterion is preferred, since the polymer backbone remains unchanged until that time. Though, it is a very conservative approach.

1.2.2 Prediction model of antioxidant depletion

During the aging process, antioxidants deplete under chemical and physical mechanisms, which were modeled by a first-order differential equation. From this equation, the antioxidant depletion is expressed in terms of OIT:

$$\ln OIT = -K_1 \cdot t + \ln(OIT_{initial}) \qquad (1)$$

Where

- OIT: Oxidative Induction Time at a duration time of t.
- $OIT_{initial}$: Oxidative Induction Time before aging.
- K_1: Depletion rate, calculated by the slope on the right side of figure 2.
- t: Duration of the exposure (hours).

In order to predict the long-term properties from short-term tests, Arrhenius model was used to accelerate the test by increasing the aging temperature. The key principles of this model are summarized on Figure 2. Essentially, this model defines a relation between a chemical reaction rate and the temperature. While adapted to the antioxidant depletion as described in equation 1, the depletion rate (K_1) was calculated at different temperatures and modeled to the following equation by curve fitting:

$$K_1 = A \cdot \exp\left({}^{-\mathrm{E_a}}\!\big/_{\mathrm{RT}} \right) \qquad (2)$$

Where

- A: Constant (ln min/hours).
- E_a: Activation Energy (J/mol)
- R: Gas Constant (8.315 J/mol K)

From equation 2, the observed trend was projected and the degradation rate could be calculated at any temperature. By inserting it in equation 1, the OIT value was projected for a given temperature.

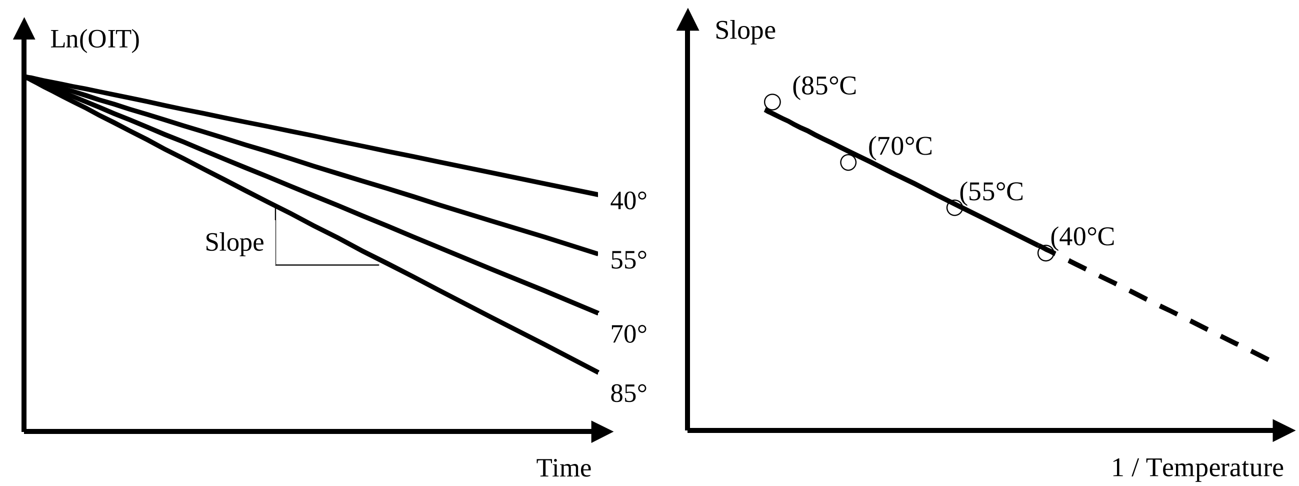

Figure 2: Key principle of the Arrhenius model

2 MATERIALS

The materials selected for this evaluation were as follows:

- A draintube, made from polypropylene resin and claimed to be representative of a typical production run by the manufacturer;
- A HDPE biplanar geonet, sampled from a geocomposite obtained from a local distributor, and claimed by the distributor to be representative of a typical geonet.

3 RESULTS

Each product were aged at four different temperatures. The OIT was plotted against time for each temperature, in order to determine the mathematical parameters linking the OIT to the time.

Although OIT is typically measured at 200°C, values measured at 180°C were used within this project as they were found to be more useful than those obtained at 200°C. This observation may be related to the type of antioxidant used in each product, which is a proprietary information.

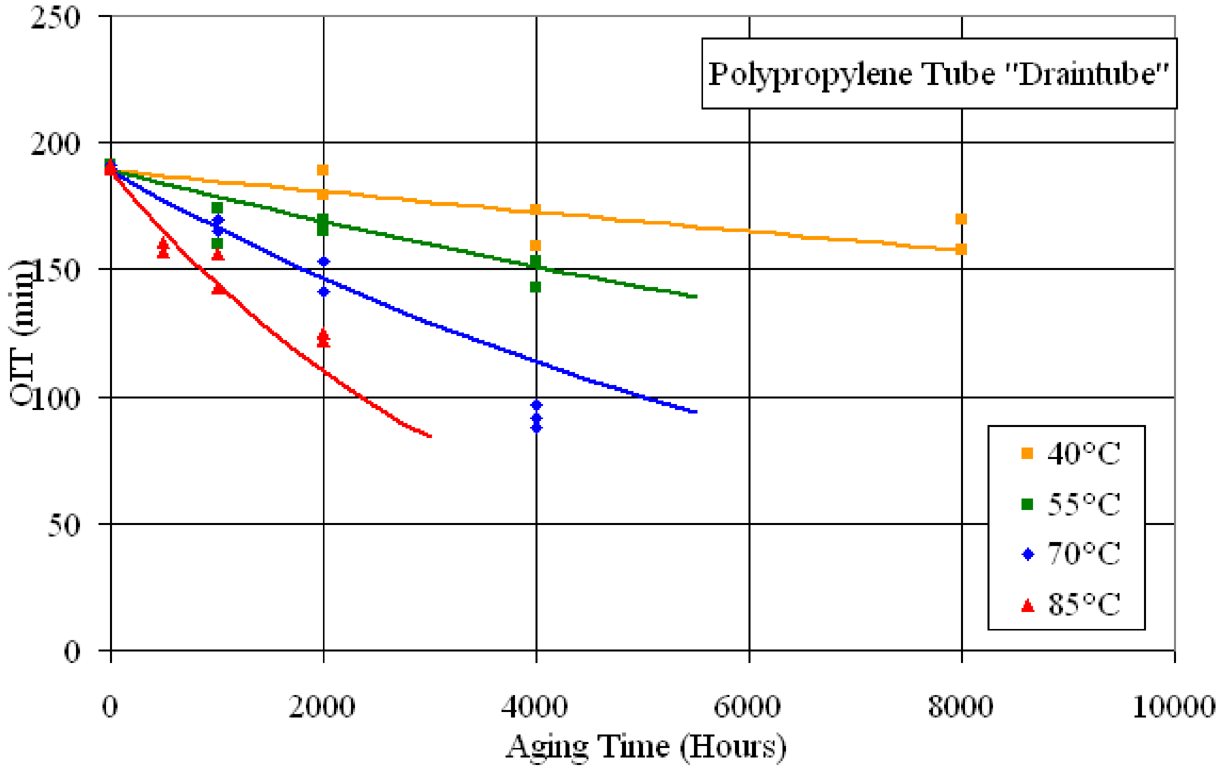

Figure 3: OIT prediction model of draintube D20

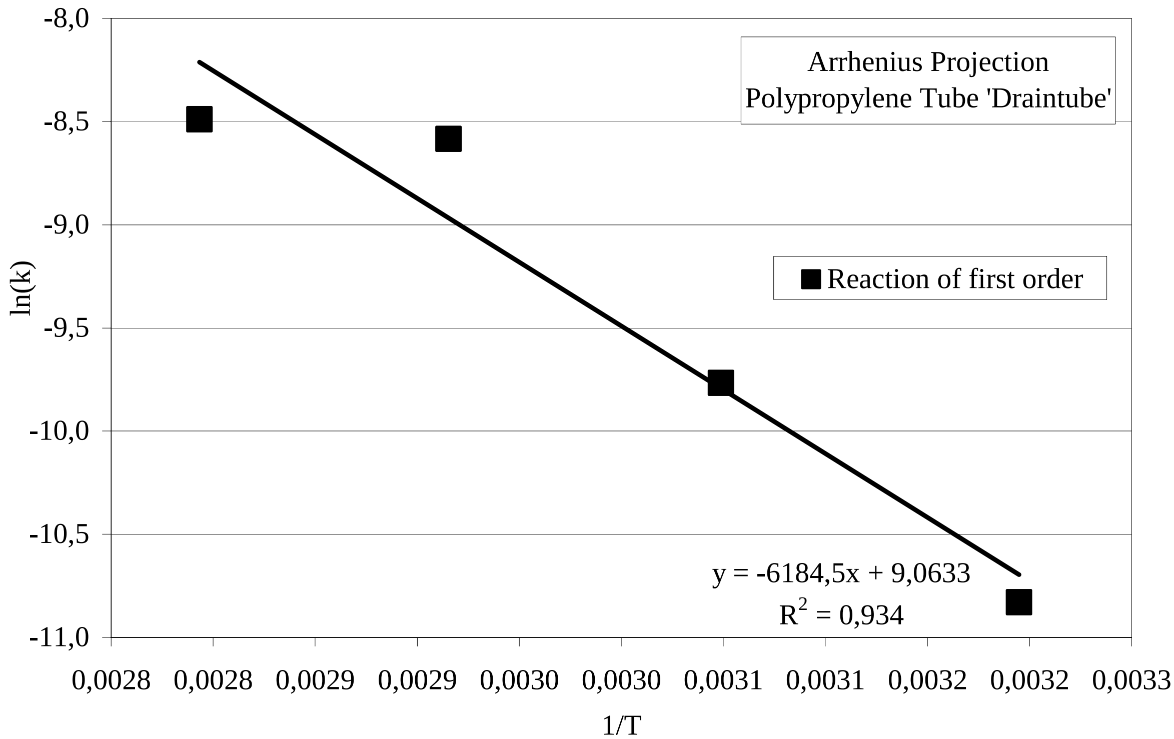

Figure 4: Arrhenius projection for Draintube

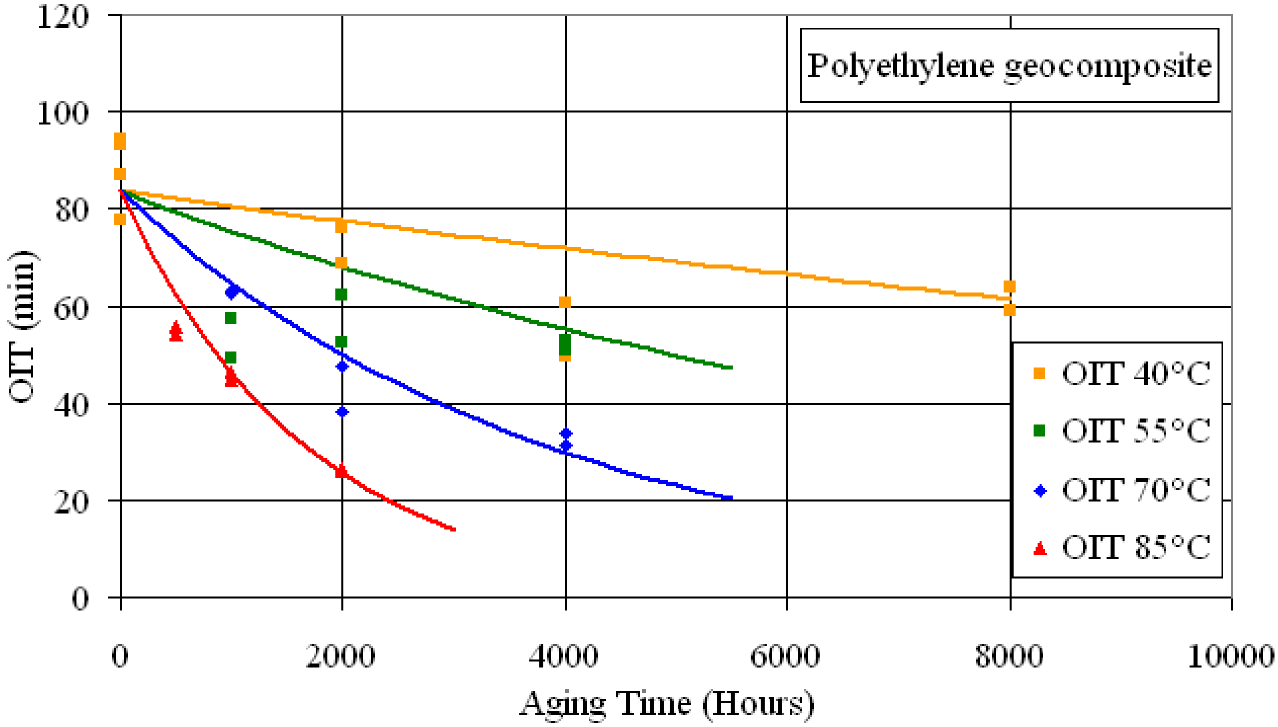

Figure 5: OIT prediction model of a HDPE geonet

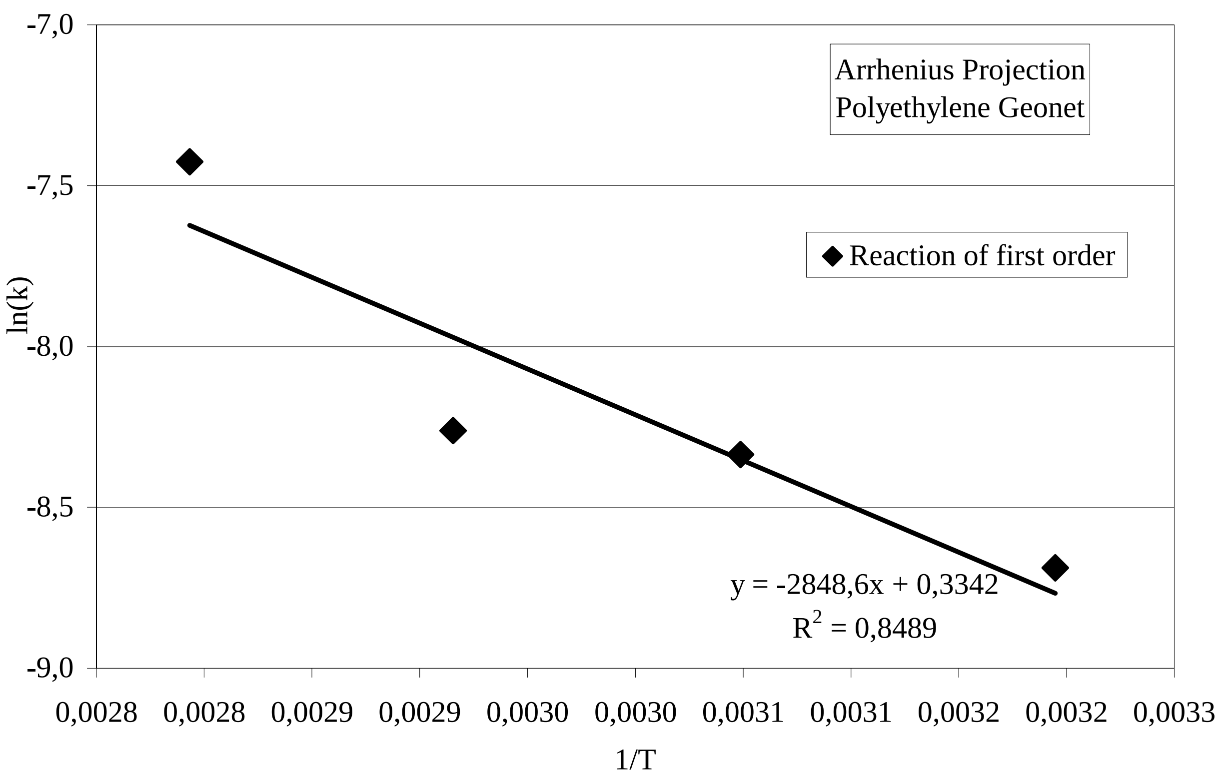

Figure 6: Arrhenius projection for HDPE Geonet

Basing on these observations, the parameters of the Arrhenius equation for OIT prediction were deducted and ploted as shown on Figures 4 and 6. The antioxidant depletion time could then be estimated considering a service temperature of 20°C.

This prediction model has shown that the draintube will be adequately protected against oxidation during an indicative duration of at least 80 years, while this duration could be approximately 40 to 100 years for the tested HDPE geonet.

Given that actual field conditions may tremendously influence the actual oxidation rate, these values shall not be considered to reflect actual service lifes. However, they can be used to assess that overall, draintube will exhibit a comparable or better resistance to oxidation than the typical HDPE biplanar geonet used as a reference material.

Table 1: Prediction of the complete antioxidant depletion (below 0.5 min OIT)

Products	Initial OIT * (min)	Activation energy (J/mol)	Depletion rate at 20°C (In min/day)	Indicative life time at 20°C (years)
Draintube	189	773	1.4×10^{-4}	80-165
HDPE Geonet	84	822	2.1×10^{-4}	40-100

* At 180 °C

4 CONCLUSIONS

Basing on the observations conducted within this project, it can be concluded that the draintube will exhibit a comparable or better resistance to oxidation than typical HDPE biplanar geonets used as a reference material.

Given that:

- Polypropylene typically exhibits a similar chemical resistance than polyethylene;
- Polypropylene typically exhibits a better resistance to creep than polyethylene;
- Polypropylene is typically not affected by stress cracking;

It can be concluded that the ‘draintube’ offers a similar or better durability than the typical geonet evaluated within this project.

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